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ABSTRACT

The effectiveness of training aids in the teaching of elementary electronics trouble shooting was tested. Students entering the Basic Electronics course at the U.S. Naval Training Center, Great Lakes, Illinois, were assigned to one of three groups being taught by either the standard Navy training method using actual operational equipment, training with actual equipment plus the Trainer-Tester, or training with actual equipment plus the Punchboard Tutor. The Trainer-Tester device presented the student with a list of the symptoms exhibited by a malfunctioning piece of equipment and required him to conduct a number of hypothetical tests and measures until he could determine the cause of the malfunction. The Punchboard Tutor device provided students with immediate correction of multiple choice questions. The performance of the three groups on examinations, laboratory grades, and overall performance was compared. Follow-up data on those trainees who went from the Basic Electronics course into Advanced Radar and Communication Schools was obtained. Students who used the training devices received higher overall grades than students who used equipment only. In Advanced Radar Training the Trainer-Tester users received better grades in Radar Laboratory. (KB)

TECHNICAL REPORT - NAVTRADEVCEN 1257-2-1

AN EVALUATION OF THE TRAINER-TESTER AND PUNCHBOARD TUTOR AS ELECTRONICS TROUBLE-SHOOTING TRAINING AIDS

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F O R E W O R D

Purpose

At the request of the Bureau of Naval Personnel, this research was undertaken to evaluate the effectiveness of specified paper-and-pencil training aids in teaching elementary electronics trouble-shooting.

To meet this objective, an experimental program was carried on in conjunction with the regular ten-week Basic Electronics course given at the U. S. Naval Training Center, Great Lakes, Illinois. Students entering the Basic Electronics course were assigned to groups being taught electronics trouble-shooting by one of the following three methods:

1. Standard Navy method, i.e., training with actual operational equipment.

2. Training with actual equipment plus Trainer Tester.

3. Training with actual equipment plus Punchboard Tutor.

The performance of the trainees in each of the three groups was compared in terms of the following scores which were obtained for each of the five two-week periods of the Basic Electronics course: course examinations, laboratory grades, weighted average of examination and laboratory grades, and scores on special trouble-shooting examinations. In addition, over-all grades for the ten-week period were analyzed.

In order to evaluate more fully any differential effects of the three methods, follow-up data were obtained for those trainees who went from Basic Electronics into Advanced Radar and Communications Schools.

Results

The major findings of the study may be summarized as follows:

1. In Basic Electronics, students who used the Trainer-Tester and the Punchboard Tutor were superior to the students who used equipment only.

2. In Advanced Radar Training, students who had used the Trainer-Tester during basic training were superior to the other groups in Radar Laboratory grades.

Implications

The results of this research indicate that the Trainer-Tester and Punchboard-Tutor can be used successfully as partial replacements for actual equipment in elementary trouble-shooting training. Their value as training aids appears to lie in their relatively low cost and their ability to teach the intellectual aspects of trouble-shooting. Their high motivational value for students is also an invaluable asset to training.

The findings of this research indicate the advisability of investigating the effectiveness of these aids in more detail in teaching on-the-job trouble-shooting proficiency as well as trouble-shooting on more complex equipment.

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INTRODUCTION

In the technical training programs of the Armed Forces, the problem of fidelity of simulation arises recurrently and in a variety of different contexts. Broadly defined, this is the problem of the degree to which actual operational situations and equipment must be simulated during training in order to produce adequately skilled technicians. On the assumption that training in real situations with actual equipment provides the optimal conditions for learning, the problem can also be stated as that of the degree to which departures from realistic conditions can be tolerated without significant proficiency losses.

In the teaching of certain kinds of skills and techniques, the use of operational equipment is both practical and economical. For example, in schools of photography it is usually feasible to provide every student with a camera and the auxiliary equipment required for the mastery of photographic procedures. The number of students is relatively small, the cameras are available in adequate numbers, and their cost is relatively low. Moreover, cameras are reasonably rugged instruments that are not too readily damaged by the fumbling hands of the novice operator. Under circumstances of this kind, therefore, there is little reason to substitute synthetic training devices for the real thing.

The technological complexities of modern warfare, however, involve many skills whose acquisition requires the use of equipment costing many thousands of dollars per unit. If the device, a fighter aircraft, for instance, is ineptly handled by the student, it may be severely damaged or totally destroyed. Moreover, the substantial amounts of money invested in developing the operator's proficiency may be lost through his death or serious injury. It is also clear that during any national emergency devices such as complex radar systems simply cannot be built with sufficient rapidity to meet the needs of all potential users, and the needs of the combat forces must usually take precedence over those of technical training agencies. High operating costs and the necessity for conserving strategic materials place additional restrictions upon the use of operational equipment for training purposes.

It is with reference to costly and complex equipment, therefore, that the use of synthetic training devices has its greatest appeal and can be defended most convincingly. But as the need for substitute training methods increases, the problem of their fidelity of simulation also becomes increasingly acute. In some instances, reasonable guesses as to the probable efficiency of a training device can be derived from previous experience with similar equipment and training methods. In the vast majority of cases, however, precise estimates of the value of synthetic training aids can only be achieved by carefully controlled research.

In the light of the above considerations, it seems likely that the field of electronics trouble-shooting training is one in which synthetic training aids might be of considerable value. Operational electronic equipment has become so elaborate and expensive that its use for routine training is almost prohibitive. It is important, therefore, that whenever potentially valuable electronic training aids are available, their utility as substitutes for the actual operational equipment be carefully and systematically evaluated. The research described in this report constitutes one attempt to carry out such an evaluation.

The principal objective of this project was to determine the relative effectiveness of three different methods of teaching electronics trouble-shooting skills. One method, which was essentially that in current use by the Navy, involved trouble-shooting training with actual equipment. The other two methods differed from this 'standard' method in that part of the laboratory work with equipment was replaced by practice with paper-and-pencil trouble-shooting training aids. These training aids, which are described in detail below, were the Trainer-Tester and the Punchboard Tutor.

If such paper-and-pencil training aids can be shown to be as effective as work with actual equipment for teaching elementary trouble-shooting skills, and if the cost of such aids is substantially less, then it would be desirable to expand their use in Basic Electronics training. The intelligent application of such trouble-shooting training devices could lead to a more effective utilization of trainees' time, to a reduction in the number of skilled individuals needed to maintain training equipment, and, perhaps to a substantial reduction in the overall costs of electronics training. Moreover, it is even possible that the complex intellectual processes characterizing much of the trouble-shooting task could be taught with even greater effectiveness by the paper-and-pencil training aids than by the more traditional methods.

Experimental Design

A description of the three experimental groups appears in Table 1, which shows for each group its alphabetical code, the type of training received, and the number of trainees in Basic Electronics. The relative efficiency of the methods was evaluated by comparing the course grades attained by the groups during Basic Electronics, Radar, and Communications training.

TABLE 1

Experimental Design

Group	Type of Trouble-shooting Training	Basic Electronics Trainees per Group
E	Work with Equipment	230
T-T	Work with Equipment plus Trainer-Tester Problems	230
P-T	Work with Equipment plus Punchboard Tutor Problems	230

It may be seen from Table 1 that there were no groups for whom work with equipment was entirely replaced by paper-and-pencil training. There seems to be considerable doubt whether any paper-and-pencil training aid could serve as a <u>complete</u> substitute for equipment training. Indeed, the consensus of opinion among personnel at the training center was that serious problems might be generated if some trainees completed the course without any actual practice in the laboratory. For these reasons, the experiment was designed to yield an evaluation of these devices as adjuncts to laboratory work, or at most, as partial substitutes for some phases of laboratory work. This decision was supported by findings from a similar experiment performed at Keesler Air Force Base (7), which is described in a later section.

Training Aids

The Trainer-Tester is a development of the firm of Van Valkenburgh, Nooger, and Neville, Inc. It is a device that presents the student with a written list of the symptoms exhibited by a malfunctioning piece of equipment and requires him to go through a number of hypothetical tests and measurements until he can determine which component is defective or what adjustment is required. Using only the Trainer-Tester sheets and a pencil, the student can think through the problem, try out alternative hypotheses, obtain information concerning the consequences of provisional attempts to correct the malfunction, and eventually discover the correct solution. In using this training aid, no practice is obtained in the manual tasks of soldering and unsoldering components or in the setting up, calibration, and use of test and measurement equipment. Practice is restricted to the intellectual, reasoning, problem-solving aspects of the trouble-shooting task.

Each student is provided with a schematic wiring diagram (Figure 1) and a corresponding pictorial wiring diagram (Figure 2) for the circuit being studied. A separate work sheet is required for each trouble-shooting problem (Figure 3). As may be seen in Figure 3, the work sheet is composed of three major sections: (1) a section labeled Trouble, describing the malfunction to be remedied, along with rules and instructions for use of the Trainer-Tester; (2) a section labeled Symptoms, from which the student can obtain all the information he needs about resistances, voltages, and signal conditions; and (3) a section headed Remedy, which provides information concerning the consequences of (hypothetical) component replacements. The information contained in the Symptoms and Remedy sections, however, is normally obscured from the student's sight by a silver-colored overlay material. In Figure 3, these silver overlays are seen as solid black vertical bars. If the student, in attempting to solve the problem, wishes to 'test' the resistance of a suspected faulty component, to 'measure' a given voltage, or to 'replace' a component, he erases the silver overlay with a pencil eraser at the appropriate spot. When he does so, the printed information is revealed beneath the overlay, and he can use the knowledge thus gained to further his problem-solving attempts. When the defective part is finally identified and 'replaced,' the letters TC, standing for 'trouble corrected,' appear in the Remedy section where the erasure has been made, and the solution is complete. The student is required to number his erasures successively in the spaces at the right of each overlay. This makes it possible for the instructor

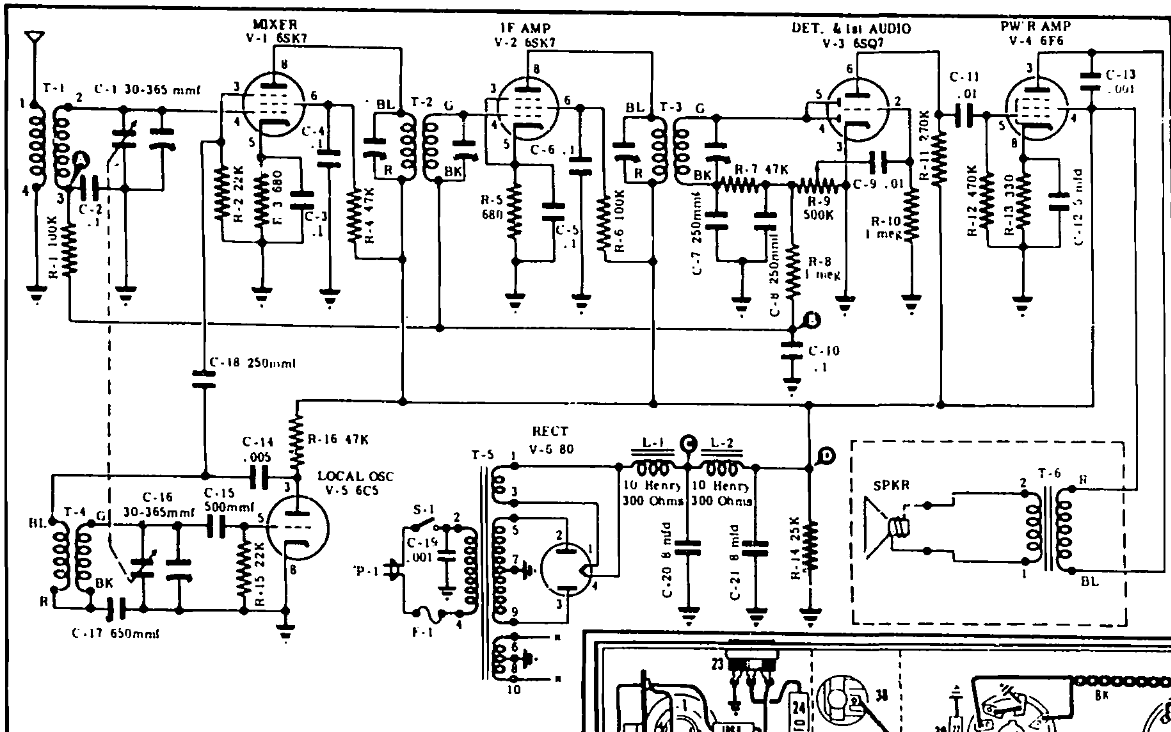
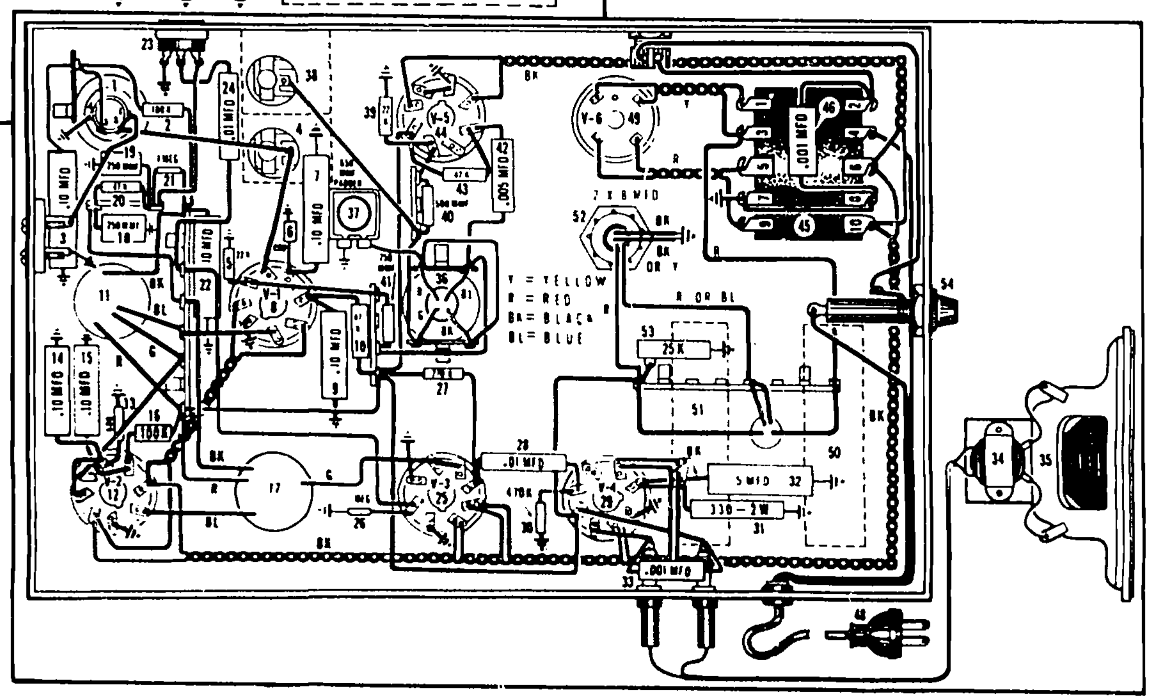


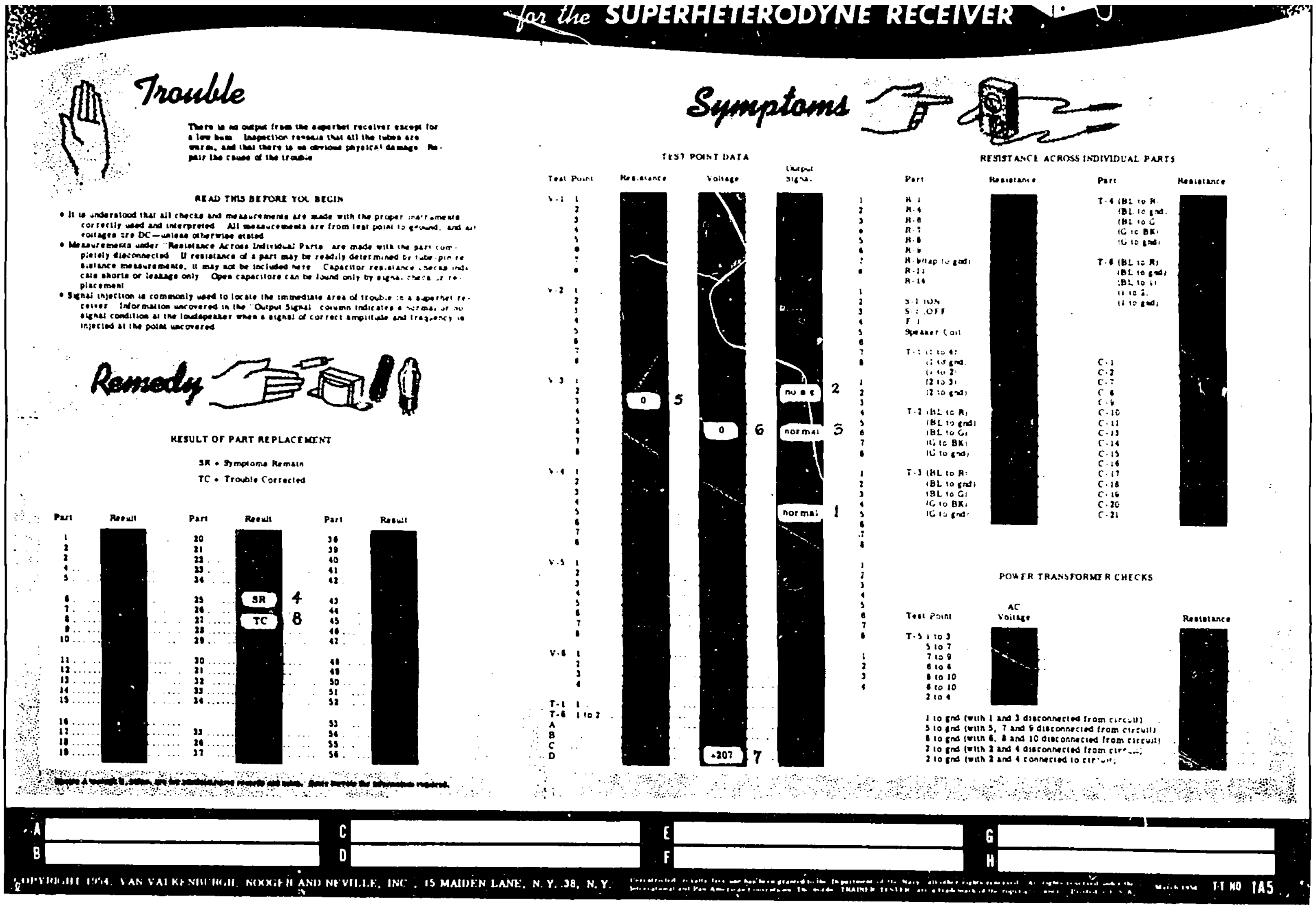
Figure 1.

Trainer-Tester
Schematic Diagram



Trainer-Tester
Wiring Diagram

Figure 2.



Trainer-Tester Work Sheet
Figure 3.

to follow the serial steps in a student's chain of reasoning, and to determine where wrong hypotheses were tested and unnecessary 'replacements' made. At the time the present study was conducted, 36 different Trainer-Tester problems were available which were suitable for use in the ten weeks of Basic Electronics training. Twelve of these problems covered malfunctions likely to be encountered in a push-pull amplifier, twelve dealt with common malfunctions of a three-stage transmitter, and twelve with superheterodyne receiver troubles.

The Punchboard Tutor (SDC Device 20-E-2e) was designed for use either as a testing device or as a self-instructing device (see Figure 4). It is constructed of layers of plastic-impregnated paper (approximately 3 1/2 in. wide, 7 1/2 in. long, and 5/8 in. thick) into which 160 holes have been punched. The holes are arranged so that the device may be used for answering multiple-choice questions. Each row of four holes is numbered and corresponds to one multiple-choice question with four possible answers. Space is provided for inserting a paper answer sheet and a pre-punched cardboard key under the top panel. The questions are presented separately on mimeographed sheets, and the student answers each question by pushing his pencil into the hole corresponding to the alternative he thinks is correct. If it is correct, his pencil goes through the answer sheet and a pre-punched hole in the key, leaving a clear hole in the sheet. If he is wrong, his pencil passes only a short distance through the answer sheet, making a much smaller hole. After each error, the student tries other answers until the correct one is obtained. In this way, the Punchboard Tutor provides the student with immediate knowledge of the correct answers to the questions. A total of eight keys is available, each one providing for a sequence of 40 questions. Frequency of errors can be determined by counting only the small holes in the answer sheet. However, the Punchboard Tutor, unlike the Trainer-Tester, provides no method for determining the order in which the errors were made.

In order to insure that students using the Punchboard Tutor would be trained on the same material as those in the group using the Trainer-Tester, all of the 36 Trainer-Tester problems were adapted for use with the Punchboard Tutor. An 'ideal' solution to each Trainer-Tester problem was prepared by a group of instructors at Great Lakes, and these sequences were then cast into multiple-choice form. A list of the trouble symptoms and the appropriate wiring diagrams were provided for each problem. The multiple-choice questions were generally sequential in nature, and by answering them correctly in order, the student was led eventually to the solution of the malfunction. The questions dealt with such matters as the kind of initial measurements to be made, the voltage or resistance readings normally obtained under certain specified conditions, the overt symptoms that would result from part replacement, etc. In so far as possible, the questions were constructed so the student could not cheat and obtain the correct solution by reading the later questions in the sequence. A sample push-pull amplifier problem is presented in Appendix A.

Related Research

A great deal of research is currently being conducted concerning all aspects of electronics trouble-shooting (1, 13). Some of these studies are directly relevant to the present investigation.

An evaluation of the superheterodyne Trainer-Testers was conducted by Dowell at Keesler Air Force Base (7). Each of four groups received 12 hours of trouble-shooting practice under one of the following conditions: 1) equipment training plus Trainer-Testers; 2) equipment training only; 3) Trainer-Testers only; 4) general trouble-shooting instructions only. After receiving the designated type of training, the students were given a performance criterion test consisting of three trouble-shooting problems on the actual superheterodyne receiver. A group of examiners graded the students' performance on a 30-point scale. The group trained on both equipment and Trainer-Testers had the best performance scores. This group performed significantly better than the group having Trainer-Testers only and better than the group having only general instructions. The group given equipment training only was significantly superior to the general instruction group. There was no significant difference between the group having Trainer-Testers only and the general instruction group.

Evaluations of the Trainer-Tester have also been conducted at Scott and Lowry Air Force Bases, but final reports of these evaluations are not available at this time. An interim report from Scott Air Force Base (14) indicates that students and instructors find the Trainer-Testers interesting and consider them valuable in learning to trouble-shoot. They found that performance on Trainer-Tester problems in terms of both errors made and time required for solution improved over a 19-week course in Radio Maintenance. However, there were no significant correlations between number of erasures and course performance test grades.

Other simulators, similar in principle to the Trainer-Tester, have been developed for presenting electronic trouble-shooting problems. Grings has described the Multiple-Alternative Symbolic Trouble-Shooting Test (MASTS Test) (9), in which the student gains information needed for solving the problem by removing corks from holes in a large panel. Each cork conceals information relevant to a particular test point. Significant correlations were obtained between performance on the MASTS Test and a performance test called the Job Sample Test (10). Bryan has described the AUTOMASTS Test, which is an automatically-recording version of the MASTS Test (2). Scores on the AUTOMASTS Test were found to correlate positively ($r = +.60$) with paper-and-pencil test scores. Composite scores based on performance on the AUTOMASTS Test and on the paper-and-pencil tests correlated significantly with other measures of technical proficiency such as amount of electronics experience, pay grade, entrance examination and final grades in Class B Electronics School, and final grades in Class A Electronics School (3).

A device very similar to the Trainer-Tester, called the Tab Test, has been described by Cornell, Damrin, Saupe, and Crowder (5). In this test, the subject gains information needed for solving the problem by removing paper tabs which cover the data, rather than by erasing a silver overlay material as in the Trainer-Tester. The Tab Test has been shown to correlate significantly with multiple-choice trouble-shooting tests and with school grades. Correlations with trouble-shooting performance tests and with on-the-job performance ratings have been quite low (8).

The AUTOMASTS Test and the Tab Test were developed primarily to be used as testing devices, that is, as criteria of job proficiency in electronics trouble-shooting. Therefore, investigators have concentrated on developing methods of scoring performance and on gathering reliability and validity data. Although the possibility of using the devices for training is suggested by these investigators, no information is available concerning their value as training devices.

METHOD

Procedure

The experiment was carried on in conjunction with the regular ten-week Basic Electronics course following the six-week Basic Electricity course at USNTC, Great Lakes, Illinois. The standardized course schedule was revised to include specified blocks of time devoted to trouble-shooting training during the third, seventh, and tenth weeks of Basic Electronics. All groups spent twelve 45-minute class periods solving trouble-shooting training problems on each of three pieces of equipment: the push-pull amplifier, the three-stage transmitter, and the superheterodyne receiver. During these periods, Group E solved trouble-shooting problems with equipment, Group T-T solved the appropriate Trainer-Tester problems, and Group P-T solved the Punchboard Tutor problems. In all groups, the students' work was followed by discussions of the problems by the instructors. In addition to these 36 periods, all groups spent approximately 34 periods trouble-shooting other pieces of actual equipment and learning to use test and measurement instruments. Every student also spent about 4.5 days building and trouble-shooting a superheterodyne receiver. In so far as possible, identical lecture and demonstration materials were provided for all groups

Orientation meetings were held for all course instructors. The research program was explained in detail to them and their cooperation was elicited in maintaining the constancy of the experimental conditions. It was emphasized that the Trainer-Tester and Punchboard Tutor were to be used as training, not testing devices. Detailed instructions were given on the procedures to be used for each of the three training methods. Although it was impossible to keep the students naive with respect to the experiment, the instructors were urged to minimize competition among the three experimental groups. A copy of the mimeographed notes handed out to each instructor is included in Appendix B.

Upon completion of Basic Electricity, the trainees were randomly assigned to class sections, and a training method was assigned to each section. A total of nine incoming classes was used, and each method was represented at least once in each class. An attempt was made to see that all instructors taught each of the three methods. Although the rotational system in the school made this impossible, 33 of the 45 instructors taught all three methods, 5 taught two methods, and 7 taught one method. Both instructors and students filled out questionnaires designed to determine their reactions to the training methods. Sample copies of these questionnaires are included in Appendix C. The different forms of the trainee questionnaire for the three groups are identified by the letters E, T-T, or P-T in the upper right corner.

All students were given trouble-shooting practice during the same periods. The schedule of periods assigned to trouble-shooting the amplifier, transmitter, and receiver is shown in Appendix D. The course instructors developed sets of trouble-shooting problems for the members of Group E to solve when working with the actual equipment. Where possible, these problems paralleled the Trainer-Tester and Punchboard Tutor problems.

Since each problem took longer using this method, the average student in Group E was only able to complete about eight problems during the twelve class periods devoted to each of the three pieces of equipment. Groups T-T and P-T spent the first trouble-shooting period on the Push-Pull Amplifier learning how to use the training device and solving the first problem as a group, with the help of the instructor. The mimeographed instructions handed out to each student may be found in Appendix E.

It was believed that any differential effects of the experimental training methods could be evaluated further by following the progress of the trainees during more advanced training, where trouble-shooting ability plays a more important role. Therefore, follow-up data were obtained for those trainees who went from Basic Electronics into Radar or Communications schools. No further differential treatment was given to the groups during this advanced training.

Subjects

All experimental subjects were trainees in the ET "A" School at USNTC, Great Lakes, Illinois, who had just completed six weeks of training in Basic Electricity. The majority of them were studying to be Electronics Technicians (ET's), but the groups also included Fire-Control Technicians (FT's), Marines, and a few Waves. Although the school was training Senior Convertees at this time, they were not included, since the staff at Great Lakes felt that the Senior Convertees were more mature and more highly motivated than the other trainees. The class lists from Basic Electricity were used to assign eligible students randomly to the experimental sections.

At the end of the ten weeks of Basic Electronics training, the ET's were assigned to advanced training in Radar, Communications, or Sonar, roughly in a 50-30-20 proportion, respectively. Those entering Radar and Communications were assigned so that there was an approximately equal representation from the three training methods. The groups entering Sonar training were not large enough to be included in the analyses of advanced training performance.

Criterion Measures

The ideal criterion measures in a study of this type would probably be objective scores from standardized trouble-shooting tests using defective equipment. The process of collecting such scores, however, is very time-consuming, and it was not possible to obtain them at Great Lakes without seriously disrupting the normal training program. It was necessary, therefore, to rely primarily upon performance in written examinations in evaluating the relative efficacy of the three training methods.

The criterion data during Basic Electronics training consisted of five sets of scores obtained for each student. The school evaluated the students at the end of each of the five two-week periods of Basic Electronics. A set of four scores was obtained for every student during each of these five periods. One score was the grade on the regular course examination, which consisted of 50 multiple-choice items including five items dealing with trouble-shooting. A second score was a laboratory grade the instructor assigned on the basis of performance in laboratory experiments and laboratory quizzes. The third score was an average which gave a 60-40 weighting to the examination and laboratory grades, respectively. The fourth score was a grade derived from special trouble-shooting examinations given at the end of each two-week period. Each examination consisted of 15 multiple-choice trouble-shooting items from the school's pool of items. The student's trouble-shooting score was the total number correct on this special examination plus the number correct on the five trouble-shooting items in the regular course examination. Overall examination, laboratory, average (exam-lab), and trouble-shooting scores were also computed for the entire ten-week period.

Scores were derived in a similar manner for advanced training in Radar and Communications. Examination, laboratory, average, and trouble-shooting grades were obtained for each two-week period in the ten weeks of Radar and the eight weeks of Communications. Since no special examinations were devised for advanced training, the trouble-shooting score for each two-week period was based on the trouble-shooting items in the course examination. Overall scores were computed for each measure as in Basic Electronics.

[illegible] scores, [illegible] Table [illegible] group means are given for [illegible], laboratory, [illegible], and trouble-shooting grades in the over-all [illegible]-week period and in each two-week period. All scores are based on a [illegible] total of [illegible] points. The last column in the table indicates the differences that are statistically significant at the 5% level or better. The uncorrected group means and standard deviations are presented in Table [illegible] in Appendix F. The F and t values obtained in the covariance analyses may be found in Table 5 in Appendix F.

It may be seen in Table 2 that the absolute differences among the groups were small. For all overall measures, the groups using Trainer-Testers and Punchboard Tutors had higher means than the group trained with equipment only. These differences were all statistically significant with the exception that Group T-T was not reliably superior to Group E in over-all trouble-shooting grades. There were no significant differences between Group T-T and Group P-T in overall grades.

TABLE 2

Group Means for Performance in Basic Electricity and Basic Electronics
N = 230 per Group

Measure	Mean E	Mean T-T	Mean P-T	Statistically Significant Differences
Basic Electricity	88.69	88.09	89.34	P-T > T-T
Overall**				
Examination	74.32	75.44	75.88	T-T > E; P-T > E
Laboratory	80.20	81.42	81.26	T-T > E; P-T > E
Average (Exam-Lab)	76.72	77.68	77.90	T-T > E; P-T > E
Trouble-shooting	63.10	64.12	64.92	P-T > E
2nd Week*				
Examination	77.10	76.74	76.06	None
Laboratory	79.27	80.97	79.58	T-T > E; T-T > P-T
Average (Exam-Lab)	77.55	77.99	77.05	None
Trouble-shooting	66.20	68.40	67.20	None
4th Week**				
Examination	72.77	74.51	74.41	T-T > E; P-T > E
Laboratory	80.99	82.12	80.80	T-T > E; T-T > P-T
Average (Exam-Lab)	75.62	77.16	76.59	T-T > E
Trouble-shooting	67.70	67.45	70.00	None
6th Week**				
Examination	73.46	75.31	75.24	T-T > E; P-T > E
Laboratory	79.36	81.75	81.96	T-T > E; P-T > E
Average (Exam-Lab)	75.42	77.40	77.59	T-T > E; P-T > E
Trouble-shooting	52.95	57.30	55.20	T-T > E; P-T > E
8th Week**				
Examination	72.89	74.14	74.97	P-T > E
Laboratory	80.47	81.54	80.16	None
Average (Exam-Lab)	75.64	76.62	76.62	None
Trouble-shooting	58.10	61.80	61.15	T-T > E; P-T > E
10th Week**				
Examination	75.88	76.01	77.62	P-T > E; P-T > T-T
Laboratory	80.68	81.95	83.19	T-T > E; P-T > E; P-T > T-T
Average (Exam-Lab)	77.47	78.01	79.49	P-T > E; P-T > T-T
Trouble-shooting	69.65	67.05	71.10	E > T-T; P-T > T-T

*Corrected for Basic Electricity performance.
**Corrected for Basic Electricity and for second-week performance.

The first section of differential trouble-shooting training for the three groups dealt with problems on the push-pull amplifier. These 12 periods occurred during the third week of Basic Electronics. It may be seen in Table 2 that, in all fourth-week measures except trouble-shooting, Group T-T was superior to Group E. No differential training occurred during the fifth and sixth weeks, which dealt primarily with oscillators and transmitters. However, both Group T-T and Group P-T were superior to Group E in all four measures for this two-week period.

The second section of differential training occurred during the seventh week, and dealt with three-stage transmitter problems. Transmitters and receivers were the major topics during this two-week period. Although there were few significant differences among the groups during this period, Group T-T and Group P-T were reliably superior to Group E on the trouble-shooting exams.

During the final two weeks, which were entirely devoted to the super-heterodyne receiver, Group P-T was consistently superior to the other groups with the exception that the difference between Group P-T and Group E in trouble-shooting was not statistically significant. Group E was significantly higher than Group T-T in trouble-shooting, this being the only significant difference in favor of Group E in the entire table.

Advanced Training

It was of interest to find out whether the differences shown during Basic Electronics would be maintained during advanced training, even though the groups received no further differential treatment. Advanced training data were obtained for a total of 210 Radar trainees and 126 Communications trainees, with an equal number having been trained under each of the three methods. Overall examination, laboratory, average, and trouble-shooting grades were each analyzed separately for the Radar and Communications trainees. Again the scores were corrected for group differences in Basic Electricity and second-week grades. There were no significant differences among the three groups in any of the measures. In fact, the groups appeared to be more alike than would be expected on the basis of chance. These findings suggested that the groups were not randomly assigned to Radar and Communications at the end of Basic Electronics, but were matched in some way. The result of such a matching procedure was to make the differences among the groups exceedingly small during advanced training. Since changes in personnel made it difficult to check on the exact sampling procedures, random samples were drawn from the available groups of trainees, and the four overall scores were re-analyzed for the random groups. Samples of 50 per group were used for Radar and 25 per group for Communications. Although only one significant F was obtained, the new values were of a magnitude that would be expected on the basis of chance. The corrected means for both the non-random and random samples are presented in Table 3. The uncorrected means for these groups and the F and t values obtained in the covariance analyses are found in Table 6 and Table 7 in Appendix F.

It may be seen in the footnote in Table 3 that Group T-T was significantly superior to both Group E and Group P-T in the overall laboratory grades during

Radar training. No significant differences were found for the Communications groups.

TABLE 3

Group Means for Overall Performance in Advanced Training

Measure	Number per Group	Mean E	Mean T-T	Mean P-T
RADAR				
Random Samples				
Examination	50	72.54	72.04	71.24
Laboratory*	50	76.56	78.16	76.52
Average (Exam-Lab)	50	73.62	74.28	73.72
Trouble-shooting	44	56.85	55.53	56.31
Non-Random Samples				
Examination	70	72.82	72.80	73.10
Laboratory	70	77.32	77.44	77.70
Average (Exam-Lab)	70	74.52	74.42	74.84
Trouble-shooting	59,67,52	57.93	55.44	57.36
COMMUNICATIONS				
Random Samples				
Examination	25	76.15	79.32	77.12
Laboratory	25	77.60	78.35	76.65
Average (Exam-Lab)	25	76.55	78.58	76.68
Trouble-shooting	25	58.55	67.80	63.55
Non-Random Samples				
Examination	42	77.70	77.55	77.65
Laboratory	42	77.62	77.48	77.22
Average (Exam-Lab)	42	77.50	77.22	77.25
Trouble-shooting	42	64.12	65.10	64.40

* Significant differences at the 5% level: T-T>E; T-T>P-T.

Correlations

Certain correlations obtained in the process of analyzing the data may be of interest, though they are not of primary concern in the experiment. The multiple correlations associated with the covariance analyses are presented in Tables 5 and 7 in Appendix F. These correlations indicate the joint relationship of Basic Electricity and second-week scores with the particular performance measure. For example, it may be seen in Table 5 that the joint correlation of Basic Electricity and second-week examination with the Basic Electronics overall examination is .84. The comparable correlations for Basic Electronics overall laboratory, average, and trouble-shooting are .78, .85, and .80, respectively. The correlations in Table 5 for the individual two-week periods were considerably lower, ranging from .31 to .71. The two-week <u>average</u> scores tended to have the highest correlations. The multiple correlations for Advanced Training are found in Table 7, Appendix F. For the random samples, these correlations range from .44 to .78. Correlations computed between overall scores in Basic Electronics and Advanced Training are presented in Table 8 in Appendix F. These correlations range from .32 to .78 with the highest values for Basic Electronics average vs. Advanced Training averages. The lowest correlations are between Basic Electronics trouble-shooting and Advanced Training trouble-shooting.

Reliability Coefficients

Reliability coefficients computed for the two training devices and two of the school's course examinations are presented in Table 9 in

Appendix F. The 12 Trainer-Tester problems for each piece of equipment were scored for total number of erasures required to achieve the solution. A total score was obtained for each individual on the odd-numbered problems and on the even-numbered problems. The odd-even coefficients, computed with the Spearman-Brown formula, were .67, .72, and .68 for the amplifier, transmitter, and receiver problems, respectively.

A similar procedure was used with the Punchboard Tutor problems, where the score was obtained by totaling the individual's errors on the comparable problems. The odd-even coefficients for the amplifier, transmitter, and receiver problems were .82, .48, and .65, respectively.

On two randomly selected Basic Electronics course examinations, the odd-even reliability coefficients were both .73. The fact that these values are lower than would be expected might be attributed to the rather narrow range of scores on the 50-item exams.

DISCUSSION

Criterion Performance

The data obtained in this study indicate that the use of the Trainer-Tester and the Punchboard Tutor, as partial replacements for trouble-shooting training with actual equipment, did not adversely affect the performance level of students thus trained. In fact, in a large majority of the comparisons of performance during Basic Electronics, the members of Group E, who had no training with the paper-and-pencil devices, performed less efficiently than the members of either Groups T-T or P-T. Furthermore, Group T-T was found to be superior to both of the other groups in terms of Radar laboratory grades. These findings support the contention that trouble-shooting exercises in the laboratory can be replaced, in part, by classroom practice with 'synthetic' trouble-shooting training aids.

The fact that Groups T-T and P-T proved to be superior to Group E during Basic Electronics, however, must be viewed with special caution. In particular, it should be pointed out that this superiority in the classroom does not necessarily imply a definite superiority with respect to trouble-shooting ability on complex shipboard equipment. Disregarding the laboratory scores for the moment, it seems likely that both the general examination scores, which contributed to the average scores, and the trouble-shooting scores, would tend to reflect mastery of the intellectual components of the trouble-shooting task. Skill in the calibration and use of measuring equipment and in the manipulation and identification of the physical components of an electronic chassis would contribute little to successful performance on these tests.

The students in Groups T-T and P-T who used the paper-and-pencil devices were, as a consequence of this special treatment, getting extended training in the intellectual aspects of trouble-shooting. It is possible, therefore, that their superiority over Group E in written examinations might be due to the fact that they were given more intensive training in these intellectual skills. It also seems likely that the superiority of Groups T-T and P-T in trouble-shooting grades resulted from the extra practice they received in answering multiple-choice questions on trouble-shooting. Furthermore, even the laboratory grades cannot be regarded as uncomplicated indices of manipulative proficiency in the laboratory, since short quizzes given in the laboratory periods contributed at least 40 per cent to the final laboratory grades. There is reason to believe, therefore, that the demonstrated superiority of Groups T-T and P-T over Group E might be uniquely dependent upon the particular criterion measures used.

It should also be noted, however, that trouble-shooting proficiency in a practical situation involves intellectual components to a considerable degree. It seems very likely, therefore, that training in the intellectualized, problem-solving aspects of the task by means of paper-and-pencil training aids would be of genuine value. Thus, students trained with such devices might, at the very least, be as competent as normally trained groups even when compared on the basis of a performance criterion.

An examination of the Basic Electronics means in Table 2 reveals that the differences between the groups are not large in absolute terms, though many are significant by the usual statistical criteria. The question may well be raised as to whether these differences would be of any practical significance. Before such a question can be answered, further research would be necessary to determine whether groups who differ with respect to the examination-score criteria also differ in the speed or accuracy with which they can repair defective shipboard-type equipment. Final judgment on the practical significance of such differences must be made in terms of the importance of these speed and accuracy factors in the actual trouble-shooting situation.

The Advanced Training data lend support for the conclusion that the paper-and-pencil trouble-shooting training did not handicap the students in their later work. Moreover, Group T-T proved to be superior to the other groups in Radar laboratory grades. Since the comparable differences were not statistically significant for Communications laboratory grades, there is not sufficient evidence to suggest that practice with Trainer-Testers provides the best single method of training. Nevertheless, these findings emphasize the possible value of further research at the more advanced level of training.

Questionnaire Data

The data obtained from the questionnaires filled out by trainees and course instructors are summarized in Appendix C. The figures indicate the percentage of individuals who chose each alternative. Certain qualitative conclusions seem to be indicated by a comparison of these percentages for the three training methods. Nearly 90 per cent of each group felt that the problems helped improve their trouble-shooting skill either somewhat or a great deal. The Trainer-Tester problems had the highest interest value, as indicated by the responses of both the students and instructors. Although the three groups of trainees felt about equally competent in the use of test and measurement equipment, the instructors felt that at least half of the students in the T-T and P-T groups were somewhat incompetent in this area. In contrast, the instructors rated only 4 per cent of Group E as being somewhat incompetent in the use of test and measurement equipment.

Relative Cost Data

It has already been pointed out in the introduction to this report that, other factors equal, synthetic training aids become of maximal significance when their use, in lieu of expensive operational devices, results in substantial savings in money or in strategic materials. In this respect, the results of the present study suggest that some degree of materiel conservation might be effected by the use of either the Punchboard Tutor or the Trainer-Tester without serious loss of trouble-shooting competence. It is beyond the scope of this study, however, to say whether the economies thus achieved would be of any real significance in times of national emergency. The use of either the Punchboard Tutor or the Trainer-Tester would be indicated in any case whenever suitable physical equipment cannot be procured for training purposes.

The problem of attempting to estimate the relative costs of trouble-shooting training with training aids and with actual equipment is an extremely complex one. Expenses incurred in the use of the Trainer-Tester and the Punchboard Tutor can be readily computed, but it is difficult to get an accurate estimate of the expense of using operational equipment for trouble-shooting training. For the purposes of this study, an initial attempt was made to obtain cost estimates of this kind from electronics instructors at Great Lakes. Unfortunately, these estimates were so variable as to be worthless. A somewhat better, though still tentative, estimate was finally obtained by computing the total cost of electronic parts and tools expended during one year in the Basic Electronics courses. A study of the curriculum in these courses showed that the 36 periods devoted to trouble-shooting constitute approximately 24 per cent of all laboratory and demonstration time. By taking 24 per cent of the total cost of parts consumed during the year, and dividing this value by the total number of men trained during the year, it was concluded that the cost of these 36 periods of trouble-shooting training was roughly $2.10 per man. This figure does not, it must be noted, include costs of original equipment, electricity, instructors' or supervisors' salaries, and the like. It is a rough estimate simply of the parts and tools expended during 36 hours of trouble-shooting training devoted to each student. By way of comparison, each man is given 36 Trainer-Tester problems, and the sheets for each problem cost about two cents. The expenses incurred in using the Trainer-Tester would, therefore, be well under $1.00 per man. In using the Punchboard Tutor, the only costs are those arising from the manufacture of the small printed answer sheets and the mimeographed sets of questions. A conservative estimate is that these materials would probably cost less than 15 or 20 cents per man. Original development costs have been ignored in making all three of these estimates.

Although no great confidence can be placed in the estimates, the best guess one can make at the present is that the Punchboard Tutor is considerably cheaper than the Trainer-Tester and that the latter, in turn, is substantially less costly than work with actual equipment. It is necessary to remember, however, that the potential economies of synthetic training aids tend to rise with increases in the price of the equipment for which training is being provided. If this is indeed the case, the economic advantages of such aids as the Trainer-Tester and the Punchboard Tutor should be enhanced considerably if they were used for trouble-shooting training on complex radar systems or other equipment rather than for training on such simple devices as push-pull amplifier, three-stage transmitters, and superheterodyne receivers.

Suggestions for Further Research

It has been demonstrated in this experiment that the training aids provide adequate or even superior training in the intellectual aspects of trouble-shooting, when compared with the traditional method of teaching trouble-shooting. The investigators feel that further evaluation of these devices is warranted by these findings, and that such efforts should be directed toward answering two questions. The first question would be concerned with the effectiveness of trouble-shooting training provided by the devices, in terms of proficiency in actual trouble-shooting. The second question would be concerned with the possible training value of the devices for more complex pieces of equipment. It seems quite likely that these training aids would find their greatest usefulness in (1) teaching the intellectual and reasoning aspects of trouble-shooting complex systems and (2) in the saving in money and materials needed for maintaining such systems for training purposes.

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to evaluate the relative effectiveness of three methods of teaching trouble-shooting to Basic Electronics trainees at USNTC, Great Lakes. One group solved amplifier, transmitter, and receiver trouble-shooting problems using only actual equipment. The other two groups received a portion of their trouble-shooting training with a paper-and-pencil training aid, using either the Trainer-Tester or the Punchboard Tutor. The performance of these three groups of trainees was compared during Basic Electronics and Advanced Training in terms of course examination, laboratory, average, and trouble-shooting examination grades. It was found that in many comparisons during Basic Electronics, the students using the training aids were superior to the students trained with equipment only. In Advanced Training, the Trainer-Tester group was superior to the other groups in Radar laboratory grades. It was pointed out that, although these training aids would appear to be useful in terms of their relatively low costs and their ability to teach the intellectual aspects of trouble-shooting, further research would be required to demonstrate their effectiveness in teaching on-the-job trouble-shooting proficiency. It is also suggested that their potential effectiveness in teaching trouble-shooting skills on more complex equipment be investigated.

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APPENDIX

APPENDIX A

PUNCHBOARD TUTOR
Push-Pull Amplifier
Sequence No. 92090-6
Code No. 1A

Please Do Not Write on These Sheets

A. Read this before you begin.

1. It is understood that the chassis is plugged into a normal source of power and that an audio signal of normal amplitude is being injected into the amplifier input.

2. Assume that all checks and measurements are made with the proper instruments, correctly used and interpreted. All measurements are from the indicated test point to ground, and all voltages are DC, unless otherwise stated.

3. Coupling capacitor resistance checks indicate shorts or leakage only. Open coupling capacitors can be found only by signal check or replacement. Open filter condensers can be located by resistance measurements.

B. Trouble.

The push-pull amplifier operates normally except that a sputtering noise is heard coming from the loudspeaker. Suddenly, all operation ceases. An inspection shows that the fuse has blown. When the fuse is replaced, it blows out as soon as the power is turned on. Find the defective component first and replace it before replacing the fuse.

1. How would you start the troubleshooting process on this case of trouble?

   A. By checking tubes
   B. By disconnecting the B-plus lead at point C
   C. By making a resistance measurement
   D. By inspecting the line-cord and the off-on switch for short circuits.

2. Which of the following defects could be responsible for the trouble symptoms?

   A. A short circuit between the ends of L-2
   B. A short circuit in C-2
   C. A short circuit between the blue and yellow leads of T-1
   D. A short circuit in R-11

3. A resistance measurement from point D to ground shows normal. What would you conclude?

   A. There is no trouble in the power supply
   B. The trouble is to the left of pins 1 and 4 on V-5
   C. The measurement gives no information at all about the trouble
   D. The trouble is probably intermittent and has been cleared by making the measurement, but may return

4. How would you proceed from here?

   A. Measure the resistance from terminal 10 on T-2 to ground
   B. Measure in turn the resistance from pins 2 and 3 of V-5 to ground
   C. Measure the resistance of C-9
   D. Measure the resistance from point A to ground

5. Approximately how many ohms of resistance would you expect to find if, in the preceding step, all components being measured were normal?

   A. 50,000 ohms
   B. 350 ohms
   C. 1 ohm
   D. Greater than 500,000 ohms

6. If much too low a value is found in Step 5, which of the following defects could be responsible?

   A. Plate-to-plate short circuit on V-5
   B. Primary-to-secondary short circuit on T-1
   C. Short circuit between the heater windings on T-2
   D. Short circuit between terminals 4 and 9 on T-2

7. Further checking shows none of the above faults. However, in Step 4 the resistance measurement from pin 3 to ground showed zero ohms. How would you prove that the power transformer is defective?

   A. By disconnecting the lead from terminal 5 of T-2 and measuring the resistance from terminal 5 to ground
   B. By disconnecting the lead from terminal 7 of T-2 and measuring the resistance from terminal 5 to ground
   C. By measuring the resistance between terminals 2 and 4 of T-2
   D. By removing the rectifier tube and measuring the resistance from terminal 5 to ground

8. A resistance of zero ohms is found in Step 7. What is the best explanation for the blown fuse?

   A. A short-circuited transformer anywhere in a receiver always causes the fuse to blow
   B. A high secondary impedance reflects a low primary impedance
   C. A low secondary impedance reflects a high primary impedance
   D. A low secondary impedance causes a low primary impedance

9. Why would it be dangerous to short circuit F-1 and plug the amplifier back into the line without replacing the defective transformer?

   A. Because of the possibility of electric shock hazard to the operator
   B. Because the transformer would overheat and possibly catch on fire
   C. Because the rectifier tube would overheat and might explode
   D. Because C-8 might overheat and burn up

10. If all the resistance measurements made in the preceding steps had resulted in normal readings, what should you have done next?

   A. Replaced C-9
   B. Checked the original symptoms again
   C. Made resistance measurements on the primary of T-2
   D. Replaced the line cord

APPENDIX B

Instructor Notes

1. Experimental Plan

Group E Equipment
Group T-T Trainer-Tester
Group P-T Punchboard Tutor

2. Remember to try and keep student enthusiasm high for all troubleshooting training, whatever method is being used. Make the most of each training method.

3. Please do not leave these sheets where students may accidentally see them. We do not want them to know that we are comparing group performance since this knowledge might lead to undesirable competition among the groups.

4. It will be important to control the number of hours each group spends in lecture and in troubleshooting practice. Each Coordinator will indicate which hours are to be spent in lecture, which are for lab work, and which are for troubleshooting practice. Try to follow these schedules as closely as possible so that we will have a good basis for comparing the three groups.

5. Approximately one hour has been scheduled for each of the Trainer-Tester and Punchboard Tutor problems in Groups T-T and P-T. Group E will spend the same number of hours actually troubleshooting equipment.

6. An important factor will be the manner in which the Trainer-Testers and Punchboard Tutors are introduced to the trainees. As far as possible, we would like to be sure that everyone gives the same orientation talks and general instructions with these devices. A general introduction to each

device has been mimeographed so that each trainee can read it before you explain how to do the problems.

7. The general procedure for the first practice hour with either the Trainer-Tester or the Punchboard Tutor will be as follows:

a. Preparation of Materials

1. Trainer-Testers: For Sequence No. 92090-6, obtain the necessary number of schematic and wiring diagrams, Trainer-Testers, and introduction sheets.

2. Punchboard Tutors: For Sequence No. 92090-6, obtain the necessary number of schematic and wiring diagrams, introduction sheets, punchboards, question sheets, answer sheets, and hole-punchers. Put the correct key in each punchboard, making sure that the holes are lined up. The number of the correct key will appear in the upper left corner of the question sheet for each Punchboard Tutor problem. Code No. 1A will designate the first column for key 1 and 1B will refer to the second column for key 1.

b. Hand out the materials and have the trainees read the introduction sheets. Ask them to save their questions until after you have gone through a sample problem.

c. Solve the first problem with the entire group, encouraging their active participation in deciding each answer or step in the sequence. Have them actually make the erasures or punch the holes just as they will do on their own for the later problems.

8. Discussion of the problems will be a very important part of the training, so expand your explanations as much as possible. Point out why the incorrect answers or procedures are wrong or why they are not as good as the preferred answers. Encourage the students to ask questions during the discussion periods. The general procedure will be to allow the class to finish each problem and then to devote the remainder of the hour to discussion. If some problems do not require a full hour, the extra time can probably be used to advantage for the later problems.

9. For Group E, your job will be to inject troubles into each trainee's apparatus, give individual instruction where necessary, and have group discussions where desirable.

10. It will always be very important to stress the fact that the Trainer-Testers and Punchboard Tutors are training, not testing devices. Assure the students that their course grades will not depend upon their performance on these devices, and encourage them to try to learn from doing the problems. For purposes of our own analysis, we will want each student's answer sheet for each problem, so be sure that each sheet is filled out and returned to Mr. Brock.

11. We will be glad to answer any questions you have about the experiment at any time, and we will be very interested in any suggestions you have. Once the experiment is started, it will not be possible to change any of the procedures which are being used. However, your comments will be helpful to us in making final recommendations to the Navy.

APPENDIX C

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Name______________________________

Questionnaire for Instructors

The information provided by this questionnaire will be very useful in interpreting the results of the experiment. Please answer the questions as accurately as you can.

1. If you had experience with all three of the training methods (Laboratory Troubleshooting Problems, Trainer-Testers, and Punchboard Tutors), which one do you think was most effective in helping your students to improve their troubleshooting skills:

	Lab	T-T	P-T
Most effective	53*	40	7
Which method was next best?	4	41	56

Please indicate the reasons for your choices: ____________________

2. In general, how much interest did your students show in the problems presented by each of the three methods?

	Lab Problems	Trainer-Testers	Punchboard Tutors
a. A great deal	48	72	45
b. Some	45	28	24
c. Not very much	7	0	21
d. Very little	0	0	10

3. How do you feel about the general troubleshooting competence of the students trained under each method?

	Lab Problems	Trainer-Testers	Punchboard Tutors
a. Very incompetent	7	7	10
b. Not very competent	24	31	38
c. Somewhat competent	52	45	48
d. Very competent	17	17	3

*The figures indicate the percentage of individuals who gave the particular response.

Instructor Questionnaire

4. How do you feel about the general competence of the students trained under each method in the use of test and measurement equipment?

Lab Problems	Trainer-Testers	Punchboard Tutors	
a. 50	a. 15	a. 4	Very competent
b. 46	b. 37	b. 33	Somewhat competent
c. 4	c. 33	c. 41	Not very competent
d. 0	d. 15	d. 22	Very incompetent

5. Please indicate whether you feel that the number of problems used with each of the three methods was "not enough," "about right," or "too many." Do this for only those pieces of equipment (Amplifier, Transmitter, or Receiver) on which you actually lectured.

	Lab Problems	Trainer-Testers	Punchboard Tutors	
Amplifier:	a. 33	a. 21	a. 6	Not enough
	b. 48	b. 79	b. 75	About right
	c. 19	c. 0	c. 19	Too many
Transmitter:	a. 42	a. 7	a. 10	Not enough
	b. 58	b. 79	b. 60	About right
	c. 0	c. 14	c. 30	Too many
Receiver:	a. 36	a. 20	a. 40	Not enough
	b. 64	b. 70	b. 40	About right
	c. 0	c. 10	c. 20	Too many

6. How would you rate the new troubleshooting procedures used for Laboratory Problems as compared with the procedures used prior to this experiment?

a. 15 New procedures much better
b. 50 New procedures somewhat better
c. 10 Old procedures somewhat better
d. 5 Old procedures much better
e. 20 No difference

Please give your reason(s): ________________

Instructor Questionnaire

7. Do you think that Groups T-T and P-T should have spent more lab time trouble-shooting actual equipment?

Trainer-Tester (T-T)	Punchboard Tutor (P-T)	
a. 32	a. 41	A great deal more
b. 57	b. 48	Somewhat more
c. 11	c. 10	No more

If you answered (a) or (b), please give your reason(s):

8. How much discussion about the experiment do you think occurred among students trained under different methods? (This does not refer to discussion among students all trained under one method.)

a. 4 Almost none
b. 32 A small amount
c. 46 A moderate amount
d. 18 A great deal

9. How much competition among the three training groups do you think resulted from knowledge of the experiment? (This does not refer to normal competition between or within sections.)

a. 0 A great deal
b. 4 A moderate amount
c. 32 A small amount
d. 64 Almost none

10. From your point of view as an instructor, which of the three methods did you enjoy teaching most?

	Lab	T-T	P-T
Most enjoyable	30	50	20
Next most enjoyable	19	26	56

Which method was next most enjoyable?

Please give your reasons:

11. Any additional comments you may care to make about any aspect of the experiment will be very helpful:

Equipment
Questionnaire for Electronics Trainees

[illegible] answer the following questions as accurately [illegible] will not appear on these sheets.

1. Do you think that the Laboratory Troubleshootin[illegible] helped you to improve your troubleshooting skill?

   a. [illegible] Not at all
   b. [illegible] Very little
   c. 44 Somewhat
   d. 44 A great deal

   Please give your [illegible]: ____________________

2. Did you find the problems interesting?

   a. 35 Very interesting
   b. 52 Mildly interesting
   c. 10 Not very interesting
   d. 3 Very uninteresting

3. What do you think about the number of problems presented on each of the pieces of equipment?

Push-Pull Amplifier	[illegible]-Stage [illegible]	Superhet Receiver
a. [illegible] Not enough	a. 22 Not enough	a. 27 Not enough
b. [illegible] All right	b. 72 All right	b. 67 All right
c. 2 Too many	c. 6 Too many	c. 6 Too many

4. How do you feel about your competence in the use of test and measurement equipment?

   a. [illegible] Very competent
   b. [illegible] Somewhat competent
   c. 12 Not very competent
   d. 1 Very incompetent

5. How would you compare yourself with other members of your class in ability to use test and measurement equipment?

   a. 3 Less competent than most
   b. 20 Somewhat below average
   c. 65 Somewhat above average
   d. 12 More competent than most

6. Additional comments: ____________________

Trainer-Tester T-T

Questionnaire for Electronics Trainees

Please answer the following questions as accurately as you can. Your name will not appear on these sheets.

1. Do you think that the Trainer-Testers helped you to improve your troubleshooting skill?

a. 2 Not at all
b. 10 Very little
c. 36 Somewhat
d. 52 A great deal

Please give your reason(s): ______________

2. Did you find the problems interesting?

a. 63 Very interesting
b. 32 Mildly interesting
c. 2 Not very interesting
d. 2 Very uninteresting

3. What do you think about the number of problems presented on each of the pieces of equipment?

Push-Pull Amplifier	Three-Stage Transmitter	Superhet Receiver
a. 28 Not enough	a. 23 Not enough	a. 33 Not enough
b. 70 All right	b. 74 All right	b. 66 All right
c. 1 Too many	c. 2 Too many	c. 1 Too many

4. How do you feel about your competence in the use of test and measurement equipment?

a. 15 Very competent
b. 68 Somewhat competent
c. 16 Not very competent
d. .5 Very incompetent

5. How would you compare yourself with other members of your class in ability to use test and measurement equipment?

a. 6 Less competent than most
b. 28 Somewhat below average
c. 59 Somewhat above average
d. 6 More competent than most

6. Would you have preferred to spend more of your lab time in troubleshooting actual equipment?

a. 33 A great deal more
b. 39 Somewhat more
c. 28 No more

If you answered (a) or (b), please give your reason(s): ______________

7. Additional comments: ______________

Punchboard Tutor

Questionnaire for Electronics Trainees

Please answer the following questions as accurately as you can. Your name will not appear on these sheets.

1. Do you think that the Punchboard Tutors helped you to improve your troubleshooting skill?

a. .4 Not at all
b. 12 Very little
c. 60 Somewhat
d. 29 A great deal

Please give your reason(s)__________

2. Did you find the problems interesting?

a. 33 Very interesting
b. 59 Mildly interesting
c. 6 Not very interesting
d. 2 Very uninteresting

3. What do you think about the number of problems presented on each of the pieces of equipment?

Push-Pull Amplifier	Three-Stage Transmitter	Superhet Receiver
a. 20 Not enough	a. 25 Not enough	a. 23 Not enough
b. 74 All right	b. 71 All right	b. 74 All right
c. 6 Too many	c. 3 Too many	c. 3 Too many

4. How do you feel about your competence in the use of test and measurement equipment?

a. 15 Very competent
b. 66 Somewhat competent
c. 17 Not very competent
d. 2 Very incompetent

5. How would you compare yourself with other members of your class in ability to use test and measurement equipment?

a. 9 Less competent than most
b. 22 Somewhat below average
c. 61 Somewhat above average
d. 8 More competent than most

6. Would you have preferred to spend more of your lab time in troubleshooting actual equipment?

a. 46 A great deal more
b. 40 Somewhat more
c. 14 No more

If you answered (a) or (b), please give your reason(s)__________

7. Additional comments: __________

Scheduled Periods for Trouble-Shooting Practice During Basic Electronics Training

Group E : Equipment
Group T-T: Trainer-Tester
Group P-T: Punchboard Tutor

1. Push-Pull Amplifier: Third Week

   a. Tuesday -- Period 9
   b. Wednesday -- Periods 6-9
   c. Thursday -- Periods 1-4, 6-8

2. Three-Stage Transmitter: Seventh Week

   a. Wednesday -- Periods 1-3
   b. Thursday -- Periods 4, 6-9
   c. Friday -- Periods 1-4

3. Superheterodyne Receiver: Tenth Week

   a. Wednesday -- Periods 1-4, 6-9
   b. Thursday -- Periods 1-4

Introduction to the Trainer-Tester

You are about to use a new development in training--the Trainer-Tester.

The Trainer-Tester is a special device that has been designed to give you a considerable amount of practical experience in troubleshooting electronic equipment. As you know, a large part of your job will be shooting trouble. To become a good troubleshooter, you need plenty of chance to use your knowledge of basic principles and procedures, and to apply your understanding of the equipment. In using the Trainer-Tester, you go about solving each problem in much the same way that you would if you were working with the actual equipment. You can, in effect, try out different troubleshooting tests to track the trouble down to a particular stage and finally to a particular component. The manner in which you think through the trouble situations will be disclosed by the trail of erasures which you make. This trail of erasures will permit your instructor to help you improve your troubleshooting ability.

The Trainer-Tester duplicates the procedure that would be followed in locating a trouble in the equipment itself. The Trainer-Tester is divided into three main parts—"Trouble," "Symptoms," and "Remedy." The "Trouble" area contains a problem describing what has happened in the operation of the equipment to indicate that something is wrong. The "Symptoms" area lists the test points in the equipment and includes the resistance, voltage, and signal conditions peculiar to the particular troubles. The test data are concealed by a covering strip which must be erased to show the reading at that point. You uncover only that information which you believe necessary and eventually come to the conclusion that you have found the faulty part. You find the code number of the part on the wiring or pictorial diagram and "replace" the part with a new one. The "Remedy" area, which has concealed answers, will indicate whether or not the replacement of the part has corrected the trouble.

While working with the Trainer-Tester, it is assumed that you are using the proper instruments in the proper manner. For example, it is assumed that you make correct use of signal generators, oscilloscopes, and output meters in making signal tracing tests. The conditions for making measurements are stated in the notes included under "Read This Before You Begin" at the bottom of the "Trouble" area.

You may want to know why most of the test data in these problems are provided only at the tube socket pins and at special test points. Detailed information for every circuit junction point necessitates duplication of data and is not required for the location of trouble. Efficient troubleshooting results from making intelligent inquiry at critical points.

There may be problems in which you suspect troubles in connecting leads, faulty solder joints, or poor mechanical connections. This type of trouble is best found by physical inspection prior to troubleshooting or after diagnosis has revealed that part replacement will not correct the difficulty. Such troubles rarely occur in high quality equipment and are not included in these problems.

Introduction to the Punchboard Tutor

You are about to use a new development in training--the Punchboard Tutor. The Punchboard Tutor is a special device that has been designed to give you a considerable amount of practical knowledge of procedures for troubleshooting electronic equipment. As you know, a large part of your future job will be shooting trouble. To become a good troubleshooter, you need plenty of chance to use your knowledge of basic principles and procedures, and to apply your understanding of the equipment. For each Punchboard Tutor problem there is a set of questions designed to help you learn to troubleshoot. These questions are in multiple-choice form, and you will answer them by punching through the hole on the punchboard which corresponds to the alternative which you think is correct. If you have chosen the correct answer, the wooden stick will make a large hole in the answer sheet. If the alternative you choose is incorrect, the stick will only go in a short distance, making a smaller hole. You will continue to punch holes until you find the correct answer. The information you get in this way should be remembered for use in later steps of the troubleshooting problem. Some of the questions will be concerned with testing procedures to be used in these trouble situations. There will be questions about measurements at critical points in the circuit, and some questions will ask about the functions of particular components. The manner in which you think through the trouble situations will be disclosed by the holes which are punched in your answer sheet. These answer sheets will permit your instructor to help you improve your troubleshooting ability.

At the top of each set of questions is a paragraph describing what has happened in the operation of the equipment to indicate that something is wrong. It is assumed in the questions that tests are being made with the proper instruments in the proper manner. For example, it is assumed that you make correct use of signal generators, oscilloscopes, and output meters in making signal tracing tests. The conditions for making measurements are stated in the paragraph which describes the trouble.

In general, the questions will be concerned with test data only at the tube socket pins and at special test points, since efficient troubleshooting results from making intelligent inquiry at critical points.

There may be problems in which you suspect troubles in connecting leads, faulty solder joints or poor mechanical connections. This type of trouble is best found by physical inspection prior to troubleshooting or after diagnosis has revealed that part replacement will not correct the difficulty. Such troubles rarely occur in high quality equipment and are not included in these problems.

APPENDIX F

Tables of Results

TABLE 4

Uncorrected Group Means and Standard Deviations
for Performance in Basic Electronics
N = 230 per Group

Measure	Group E Mean	Group E S.D.	Group T-T Mean	Group T-T S.D.	Group P-T Mean	Group P-T S.D.
Overall						
Examination	74.52	7.68	74.80	8.28	76.30	8.08
Laboratory	79.94	5.14	81.44	5.00	81.52	4.96
Average	76.72	6.34	77.36	6.48	78.22	6.62
Trouble-shooting	62.64	10.87	63.73	11.45	65.73	11.41
2nd Week						
Examination	77.07	10.10	75.93	10.92	76.89	11.06
Laboratory	79.26	7.10	80.63	6.85	79.93	7.92
Average	77.53	7.47	77.37	8.07	77.68	8.53
Trouble-shooting	66.15	18.00	67.30	18.30	68.35	18.65
4th Week						
Examination	72.90	10.02	73.75	10.60	75.02	10.54
Laboratory	80.64	7.72	82.25	6.74	81.01	7.05
Average	75.61	7.73	76.74	7.89	77.02	8.14
Trouble-shooting	67.25	16.10	66.95	17.85	70.95	15.65
6th Week						
Examination	73.58	9.07	74.73	10.57	75.70	9.99
Laboratory	79.25	7.38	81.53	6.43	82.29	5.90
Average	75.41	7.13	77.06	7.89	77.94	7.39
Trouble-shooting	52.90	11.90	56.85	12.25	55.70	13.00
8th Week						
Examination	73.05	10.23	73.63	9.17	75.31	9.17
Laboratory	80.37	6.79	81.30	7.04	80.50	6.60
Average	75.63	7.51	76.33	7.20	76.91	6.85
Trouble-shooting	57.80	13.95	61.45	14.60	61.80	15.80
10th Week						
Examination	76.02	9.65	75.39	11.12	78.11	9.77
Laboratory	80.56	7.07	81.69	6.56	83.57	6.98
Average	77.46	7.46	77.63	8.33	79.88	7.74
Trouble-shooting	69.30	16.25	66.45	16.45	72.00	16.25

TABLE 5

Results of Statistical Analyses of Performance in Basic Electricity and Basic Electronics

N = 230 per Group

Measure	F	df	t - value (E)-(T-T)	t - value (E)-(P-T)	t - value (T-T)-(P-T)	r or R*
Basic Electricity	3.81	2, 687	1.31	1.44	2.76	
Overall						
Examination	7.02	2, 685	2.74	3.82	1.08	.84
Laboratory	6.49	2, 685	4.08	3.55	< 1	.78
Average	6.74	2, 685	3.07	3.77	< 1	.85
Trouble-shooting	4.35	2, 685	1.63	2.91	1.28	.80
2nd Week						
Examination	.88	2, 686				.60
Laboratory	4.07	2, 686	2.67	< 1	2.18	.37
Average	1.27	2, 686				.61
Trouble-shooting	1.13	2, 686				.49
4th Week						
Examination	3.57	2, 685	2.40	2.26	< 1	.66
Laboratory	3.43	2, 685	2.17	< 1	2.53	.63
Average	4.91	2, 685	3.00	1.89	1.11	.71
Trouble-shooting	2.43	2, 685				.58
6th Week						
Examination	3.63	2, 685	2.40	2.31	< 1	.55
Laboratory	13.62	2, 685	4.40	4.78	< 1	.47
Average	9.85	2, 685	3.65	4.00	< 1	.62
Trouble-shooting	8.10	2, 685	3.96	2.05	1.90	.31
8th Week						
Examination	4.03	2, 685	1.70	2.83	1.13	.57
Laboratory	2.86	2, 685				.45
Average	2.15	2, 685				.62
Trouble-shooting	5.53	2, 685	3.00	2.48	< 1	.46
10th Week						
Examination	3.02	2, 685	< 1	2.25	2.08	.59
Laboratory	10.63	2, 685	2.32	4.59	2.27	.52
Average	7.11	2, 685	< 1	3.64	2.66	.65
Trouble-shooting	6.53	2, 685	2.02	1.12	3.14	.53

* Correlations between control variable(s) and criterion measure.

TABLE 6

Uncorrected Group Means and Standard Deviations for Overall Performance in Advanced Training

Measure	Number per Group	Group E Mean	Group E S.D.	Group T-T Mean	Group T-T S.D.	Group P-T Mean	Group P-T S.D.
RADAR							
Random Samples							
Examination	50	72.56	7.10	73.12	7.56	70.12	7.80
Laboratory	50	76.64	4.80	78.60	4.12	76.00	3.80
Average	50	73.80	5.58	75.16	5.58	72.68	5.80
Trouble-shooting	44	56.58	11.46	57.00	11.91	55.08	12.90
Non-Random Samples							
Examination	70	72.68	8.30	73.08	7.02	72.94	8.40
Laboratory	70	77.12	5.54	77.66	4.40	77.66	4.06
Average	70	74.32	6.60	74.72	5.16	74.74	6.14
Trouble-shooting	59,67,52	57.30	12.06	56.46	12.33	56.76	12.51
COMMUNICATIONS							
Random Samples							
Examination	25	74.00	8.05	78.80	7.08	79.80	8.02
Laboratory	25	76.30	6.10	77.90	6.30	78.40	7.10
Average	25	74.70	6.98	78.30	6.28	78.80	5.58
Trouble-shooting	25	56.20	15.80	66.70	15.38	67.00	11.88
Non-Random Samples							
Examination	42	77.20	8.28	77.38	7.88	78.32	7.62
Laboratory	42	77.02	6.35	77.62	6.62	77.68	7.18
Average	42	77.02	6.90	77.25	6.70	77.75	5.98
Trouble-shooting	42	63.32	16.78	64.88	15.05	65.42	17.12

TABLE 7

Results of Statistical Analyses of Performance
in Advanced Training

Measure	Number per Group	F	df	R*
RADAR				
Random Samples				
Examination	50	.71	2, 145	.63
Laboratory	50	3.12**	2, 145	.51
Average	50	.33	2, 145	.68
Trouble-shooting	44	.16	2, 127	.48
Non-Random Samples				
Examination	70	.05	2, 205	.64
Laboratory	70	.20	2, 205	.54
Average	70	.31	2, 205	.69
Trouble-shooting	59,67,52	.75	2, 173	.44
COMMUNICATIONS				
Random Samples				
Examination	25	1.67	2, 70	.70
Laboratory	25	.50	2, 70	.53
Average	25	2.10	2, 70	.78
Trouble-shooting	25	2.84	2, 70	.44
Non-Random Samples				
Examination	42	.14	2, 121	.60
Laboratory	42	.05	2, 121	.55
Average	42	.03	2, 121	.68
Trouble-shooting	42	.05	2, 121	.27

* Correlation between control variables and criterion measure.
** Significant at the 5% level. The following t - values were obtained:

(E)-(T-T)	(E)-(P-T)	(T-T)-(P-T)
2.13	< 1	2.18

TABLE 8

Correlations Between Overall Basic Electronics Grades and Overall Advanced Training Grades

	N	Correlation
Basic Electronics vs. Radar		
Overall Examination	147	.71
Overall Laboratory	147	.60
Overall Average	147	.75
Overall Trouble-shooting	147	.45
Basic Electronics vs. Communications		
Overall Examination	123	.68
Overall Laboratory	123	.55
Overall Average	123	.78
Overall Trouble-shooting	123	.32

TABLE 9

Reliability Coefficients for Trainer-Tester Problems, Punchboard Tutor Problems, and Course Examinations*

	N	Reliability
<u>Trainer-Tester</u>		
Amplifier Problems	100	.67
Transmitter Problems	100	.72
Receiver Problems	100	.68
<u>Punchboard Tutor</u>		
Amplifier Problems	200	.82
Transmitter Problems	200	.48
Receiver Problems	200	.65
<u>Basic Electronics Examinations</u>		
2nd Week	79	.73
10th Week	85	.73

*Odd-Even reliabilities were computed using the Spearman-Brown Correction Formula.